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Title:
SCANNED ILLUMINATION FOR LIGHT VALVE VIDEO PROJECTORS

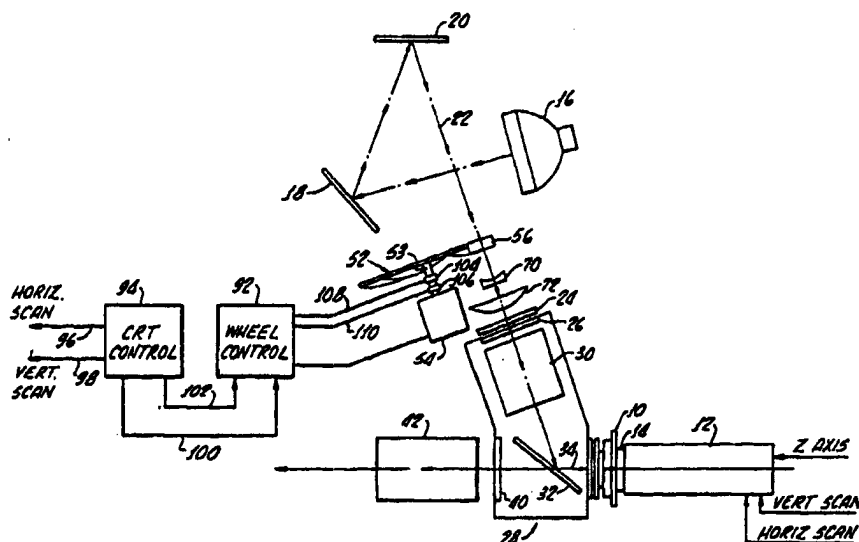
Abstract:

A video projection system employs a reflective light valve (10) that is optically addressed by an image from a cathode ray tube (12) and provides an output image for projection by means of a high intensity reading light directed to the output face of the liquid crystal light valve. Improved reading illumination is provided by scanning the face of the liquid crystal light valve (10) with a narrow beam of light (80) that moves across the liquid crystal in synchronism with the scanning image from the writing CRT (12). The scanned narrow band (80) of illumination is provided by a circular sequence of three quasi cylindrical lenses (56, 58, 60) or mirrors (56a, 58a, 60a) mounted on a rotating wheel (52) and which may be made of sequentially different colors to provide a color display. Rotation of the lens or mirror bearing wheel (52) is synchronized with the vertical sync of the CRT scan, as are the index positions of each of the three lens or mirror segments on the wheel.



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(54) Title: SCANNED ILLUMINATION FOR LIGHT VALVE VIDEO PROJECTORS**(57) Abstract**

A video projection system employs a reflective light valve (10) that is optically addressed by an image from a cathode ray tube (12) and provides an output image for projection by means of a high intensity reading light directed to the output face of the liquid crystal light valve. Improved reading illumination is provided by scanning the face of the liquid crystal light valve (10) with a narrow beam of light (80) that moves across the liquid crystal in synchronism with the scanning image from the writing CRT (12). The scanned narrow band (80) of illumination is provided by a circular sequence of three quasi cylindrical lenses (56, 58, 60) or mirrors (56a, 58a, 60a) mounted on a rotating wheel (52) and which may be made of sequentially different colors to provide a color display. Rotation of the lens or mirror bearing wheel (52) is synchronized with the vertical sync of the CRT scan, as are the index positions of each of the three lens or mirror segments on the wheel.

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SCANNED ILLUMINATION FOR LIGHT VALVE VIDEO PROJECTORS

BACKGROUND OF THE INVENTION1. Field of the Invention

The present invention relates to reflective light valve projection systems and more particularly concerns improved reading light for such a system.

2. Description of Related Art

The liquid crystal light valve (LCLV) is a thin film, multi-layer structure comprising a liquid crystal layer, a dielectric mirror, a light blocking layer and a photosensitive layer, all sandwiched between two transparent electrodes. In a reflective liquid crystal light valve projection system, a polarized projection (reading) beam is directed through the liquid crystal layer to the dielectric mirror, which reflects it back through the liquid crystal layer. The LCLV is optically addressed by an input image of low intensity light, such as that generated by a cathode ray tube, which is applied to the photosensitive layer. Impedance of the photosensitive layer is lowered in proportion to intensity of incident writing light, resulting in a spatially varying impedance pattern. This results in a corresponding increase in voltage dropped across the liquid crystal layer in a spatially varying pattern matching the incident writing

1 image. Tilt of the liquid crystal molecules in a
particular region, and therefore the birefringence seen by
the reading light passing through the region, is directly
dependent on voltage dropped across the liquid crystal
5 layer. To read the birefringence pattern, a fixed beam of
linearly polarized projection light from a high power light
source floods the output face of the liquid crystal layer,
passes through the liquid crystal layer and is reflected
from the dielectric mirror to be polarization modulated in
10 accordance with the input (writing) light information
incident on the photosensitive layer. Therefore, if a
complex distribution of light, for example a high
resolution input image from the cathode ray tube, is
focused on the photosensitive surface, the device converts
15 the relatively low intensity input image into a high
intensity replica image which can be reflected for
projection with magnification to produce a high brightness
image on a large viewing screen.

Projection systems of this type are described in
several U. S. Patents, including U. S. Patents 4,650,296 to
20 Koda et al for Liquid Crystal Light Valve Color Projector,
4,343,535 to Bleha, Jr. for Liquid Crystal Light Valve,
4,127,322 to Jacobsen, et al for High Brightness Full Color
Image Light Valve Projection System, and 4,191,456 to Hong,
25 et al for Optical Block for High Brightness Full Color
Video Projection System.

In the liquid crystal light valve projection system a
significant amount of power is used by the high intensity
light source. In the prior art, the light source provides
30 a fixed area reading illumination that covers the entire
area of liquid crystal. This high intensity reading light
is not employed with optimum efficiency nor optimum
contrast. In present systems the incoming reading light
beam frequently has a circular area, whereas the active
35 area of the liquid crystal light valve has a rectangular
configuration with an aspect ratio, for example, in the

1 order of 16:9 in some systems. Therefore significant parts
of the reading light are wasted because they fall on
inactive areas. Further, as the liquid crystal light valve
is optically addressed in a rectangular raster scan (by a
5 standard CRT scan), a major amount of reading illumination
continues to impinge upon various areas of the liquid
crystal after a line of information of the raster scan has
been written. The effect of the optically written input
information, which is written line by line in the
10 conventional raster scan, decreases with time after the
individual line is energized. Consequently, continued
application of high power, high intensity reading light
decreases in efficiency with time following the writing of
the input information. In many projectors, maximum
15 allowable light input intensity is limited by allowable
light valve temperatures so that the overall output
intensity may be limited unnecessarily by inefficient use
of the high intensity reading light.

Accordingly, it is an object of the present invention
20 to provide a liquid crystal light valve projection system
which avoids or minimizes above mentioned problems.

SUMMARY OF THE INVENTION

In carrying out principles of the present invention in
25 accordance with a preferred embodiment thereof a liquid
crystal light valve, which is optically addressed by an
input write beam that scans the area of the liquid crystal,
is provided with a high intensity reading light that
illuminates only part of the active area of the liquid
30 crystal. The illuminated area is caused to scan over the
entire liquid crystal active area in synchronism with the
writing scan. For use with a conventional rectangular
raster input scan the reading light is provided as a band
of high intensity light that scans in synchronism with the
35 input scan. In a particular embodiment the scanning
reading light is provided by a train of quasi cylindrical

1 light bending elements that are sequentially interposed
between the high intensity reading light source and the
liquid crystal. Preferably the quasi cylindrical light
bending elements are mounted on a circular wheel which
5 rotates to sequentially interpose the bending elements
between the light source and the liquid crystal to cause a
narrow elongated band of light to scan in synchronism with
the input scan.

10 BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 illustrates basic components of a liquid
crystal light valve projector having improved reading
illumination according to one embodiment of the present
15 invention;

FIG. 2 is a plan view of a lens element bearing
wheel;

FIG. 3 illustrates the configuration of a single
lens element;

20 FIGS. 4 and 5 schematically illustrate a top view
and a side view of the light path through and from the
light bending element;

FIG. 6 graphically illustrates a temporal
variation of output light intensity in a liquid crystal
light valve having fixed illumination of the prior art;
25

FIG. 7 is a view of a rectangular liquid crystal
face illustrating its illumination by a narrow band of
light synchronized with a vertical scan;

FIG. 8 is a simplified block diagram of an
electronic control for the rotating wheel;
30

FIG. 9 illustrates an embodiment of the invention
illustrated in FIG. 1 employing reflective light bending
elements;

FIG. 10 shows a wheel having reflective light
bending elements; and
35

1 FIG. 11 is a side view of the reflective wheel of
FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENT

5 Schematically illustrated in FIG. 1 are components of
a known liquid crystal light valve projector which is
modified to incorporate scanned illumination of reading
light according to one embodiment of the present invention.
The projector first will be described as it would be
10 without the components of the present invention. A liquid
crystal module 10 is optically addressed by an image
provided from a cathode ray tube 12 via a fused fiber optic
face plate 14. A high intensity xenon arc lamp 16 provides
reading light which is reflected from first and second cold
15 mirrors 18, 20 and transmitted along a path 22 through an
ultraviolet filter 24 to an input window 26 of a light
polarizing prism 28 having a pre-polarizer filter 30 and a
reflecting/transmitting polarization mirror, such as a
MacNeille prism 32. Projector components of the present
20 invention, including elements 50, 52, 54, 56, 70 and 72,
which are positioned between cold mirror 20 and the
ultraviolet filter 24 at prism window 26, are temporarily
ignored in initial discussion of projector operation.
Polarized light strikes the MacNeille prism 32, which
25 transmits light of one polarization state and reflects
light of a second polarization state. Light reflected from
prism 32 travels along path 34 to the output face of the
liquid crystal module. This is the reading light that is
reflected from the liquid crystal module. Intensity of the
30 reflected reading light varies spatially over the face of
the liquid crystal in accordance with spatial variations of
intensity of the optical image that is applied as a writing
input from the cathode ray tube and its fused fiber optic
face plate 14. Briefly, those areas of the liquid crystal
35 light valve that receive light from the cathode ray tube
reflect the high intensity reading light with a

1 polarization that allows the reflected light to be
transmitted through the MacNeille prism and through an
output window 40 of the prism to a projection lens 42 for
projection on a suitable screen (not shown). Areas of the
5 liquid crystal that are dark, e.g. those that receive no
input illumination, reflect light with unchanged
polarization state, which accordingly cannot pass through
the MacNeille prism 32, and which is thus reflected by the
prism 32 out of the system. Consequently, a high intensity
10 image of the low intensity input light from the cathode ray
tube is reflected from the liquid crystal to the projection
lens for projection.

In the past, the reading light provided from the arc
lamp, the mirrors and pre-polarizer filter has had a fixed
15 area, steady state beam that illuminates the entire face
(and more) of the liquid crystal module. The latter has an
active area that may be of various dimensions, and in some
typical embodiments may be of a circular configuration of
approximately two inches in diameter or less, or may have
20 a rectangular configuration of one and one-half inches in
vertical dimension by two inches in width, giving about a
two and one-half inch diagonal on the rectangle. The
reflected reading light is of sufficient intensity to allow
a good clear image of this relatively small area display to
25 be expanded and projected on a screen in dimensions of as
much as fifteen by twenty feet, for example.

As previously mentioned, this type of prior art fixed
position illumination has a number of problems which in
general limit operation of the liquid crystal light valve
projector and decrease its efficiency. Much of the fixed
30 area light falls outside of the active area of the liquid
crystal and thus is totally wasted. For example, assuming
a uniform illumination density and a 3:4 aspect ratio of a
normal television set and of many computer displays, 38.4%
35 of a fixed circular uniform light having a diagonal
dimension equal to or slightly larger than the active area

1 diagonal falls outside of the active raster scan so that
nearly 40% of the input reading light is lost. Moreover,
in many optically addressed liquid crystal light valve
projection systems the input light is provided in a
5 conventional raster scan, such as produced by a
conventional television set. In such a conventional scan
the horizontal scan velocity is very high, but vertical
scan velocity provides but 60 fields a second. The
conventional scan effectively moves vertically down the
10 screen in a line by line scan. Accordingly, the fixed
illumination by reading light of the prior art liquid
crystal light valve projector illuminates areas of the
light valve raster scan after a particular line has been
written. After each scan line is written, the activated
15 screen area decays in intensity from the intensity of its
freshly written condition. Since the output of the liquid
crystal light valve depends in part upon the intensity of
the input or writing illumination, the fixed reading
illumination of the prior art will cause perceived
20 brightness and contrast to be reduced by a factor of more
than two for fast light valves when used with real time
video.

FIG. 6 illustrates the temporal light pattern of
reflected reading light located at the start of the raster
25 in a typical liquid crystal light valve, showing reflected
light intensity vertically against field time (field of the
input raster) along the horizontal axis. It will be seen
that the reflected light intensity peaks at a point
indicated at 46 shortly after the beginning of the field
time. The delay in the peak with respect to the beginning
30 of the field time represents the response time of the
liquid crystal, since the output intensity of the latter
actually peaks a short time after it receives its maximum
stimulation. This intensity peak 46 moves vertically with
35 the vertical writing light beam. FIG. 6 thus indicates the

1 temporal decay that further decreases efficiency of the
fixed reading illumination of the prior art.

In accordance with principles of the present
invention, as illustrated in one particular embodiment
5 thereof, a fixed reading illumination beam is replaced by
a shaped moving reading illumination beam. The shaped
illumination beam is applied only to an area of the liquid
crystal light valve that is less than the entire active
area, so that this smaller area reading light illumination
10 is caused to track or move in synchronism with the writing
light input. Preferably no part of the shaped reading
light falls outside of the liquid crystal active area.
Specifically, with a rectangular raster writing scan in the
form of a line of input light that effectively moves
15 vertically on the screen line by line, the reading light is
also configured to provide a narrow horizontal line or band
that illuminates an area of the liquid crystal that is
simultaneously being illuminated by the input writing
light. This band of reading illumination is caused to move
20 vertically across the active area of the liquid crystal in
synchronism with the vertical scan motion of the input
rectangular scan raster.

There are a number of different optical and
optical/mechanical systems that may be employed to provide
25 a narrow line or band of illumination that scans the light
valve reading face in synchronism with the rectangular
raster scan of the input writing light. These include both
refractive and reflective elements. For example, one could
use a galvanometer operated oscillating mirror. However,
30 because of the size and mass of the oscillating mirror, a
line of light of sufficient width may be difficult to
obtain with adequate scan speeds. Accordingly, it is
presently preferred to use one or more of several different
types of rotary devices. FIG. 1 illustrates one such
35 rotary device with further details of its optical elements
shown in FIGS. 2, 3, 4 and 5. According to one embodiment

1 of the present invention, there is interposed between the
arc lamp 16, more specifically, between the reflective cold
mirror 20 and the input of the polarizing prism at
ultraviolet filter 24, a beam shaping and scanning
5 mechanism. This mechanism comprises a rotatably mounted
wheel 52 driven about an axis 53 by a motor 54 and bearing
on its outer periphery a plurality of transparent lens
elements 56, 58, 60 respectively (FIGS. 1, 2 and 3). The
three lens elements extend around the periphery of the
10 wheel in a narrow peripheral and concentric band, as can be
seen in FIG. 2. Each is formed, in this refractive
embodiment, of a quasi cylindrical lens that is bent around
and secured to the periphery of the flat side of the wheel.
The wheel is transparent over the areas of the lens
15 elements to allow light to be transmitted through the lens
elements.

Each lens has a width in the direction of the radii of
the wheel that is uniform but has a thickness in a
direction parallel to the rotation axis of the wheel that
20 increases from one end, such as end 62 of lens element 56,
to a maximum at a center point and then decreases uniformly
to a similar minimum at the opposite end 64 of the same
lens element 56. The change in thickness is preferably in
the form of a smooth curve, as illustrated in FIG. 3, which
25 shows thickness of the lens element tapering in a smooth
curve from a minimum at edge 62 to a maximum at a midpoint
68 and thence decreasing in a smooth curve to the other end
of this lens element 64. Accordingly, each lens element
has a varying refractive angle along its length. The three
30 light bending lens elements in this embodiment, which may
be considered to be a black and white embodiment for
example, are each identical and each transparent, with no
color filtering or color changing characteristics or
coatings. The three light bending elements 56, 58 and 60,
35 each extending 120° around the wheel, are positioned in a
circular train, end to end, so that as the wheel rotates

1 each in turn is interposed and moved in a circular path whose plane is perpendicular to the reading light axis.

Interposed between the light path and the train of lens elements is a fixed position negative cylindrical lens
5 70 (FIG. 1) that has little effect upon the slowly converging beam from bending element 56 in the vertical or scan direction, but which, in the horizontal or orthogonal direction, causes the beam to diverge as shown in FIGS. 4 and 5. A plano-convex lens 72 collimates the divergent
10 axis of the beam and causes the beam in its scanning direction (the vertical direction) to converge more rapidly to a line or narrow band at the active area of the output face of the light valve. Thus, as illustrated in FIG. 4, the high intensity reading light reflected from the arc
15 lamp is basically collimated as it passes through lens element 56, and thence impinges upon negative cylindrical lens 70. The latter causes the beam to diverge as it is transmitted to plano-convex lens element 72, which, in turn, directs the diverged or horizontally spread beam into
20 a wide beam that extends substantially across the entire width of the active area of the liquid crystal 10.

As can be seen in the orthogonal view of FIG. 5, a lower part of the downwardly (as viewed in FIG. 5) moving light bending lens element 56 receives incoming light and
25 refracts it according to the particular angle of its forward surface 76. The lower part of the lens element refracts the beam upwardly toward the top of the elongated negative cylindrical lens 70 in a slightly vertically converging path to be refracted through an upper portion of
30 plano-convex lens 72, which further narrows the vertical dimension of the beam to cause it to impinge in a relatively narrow band that extends across the width of a liquid crystal 10.

Also illustrated in FIG. 5 in dotted lines is the
35 position of the lens element 56 relative to the light beam after the lens element has moved downwardly to cause the

1 incoming light beam to strike an upper portion of the lens
element. Thus it will be seen that as the wheel rotates, the
light bending element 56 moves downwardly, in this
exemplary illustration, across the path of the light beam
5 so that in an initial position the light beam is bent
upwardly to impinge upon an upper end of the liquid crystal
active area. As the bending element moves downwardly, the
bending of the light beam is changed so that the narrow
band of impingement of the light beam upon the liquid
10 crystal active area moves downwardly from its area of
impingement near the top of the liquid crystal, as
illustrated in solid lines, to an area of impingement at
the bottom of the liquid crystal, as illustrated in phantom
lines in FIG. 5.

15 Illustrated in FIG. 7 is the narrow band 80 of light
that is achieved by the illustrated mechanical/optical
light bending lens elements shown in FIGS. 1, 2, 3, 4, and
5. Although a more narrow band of light is theoretically
more efficient, limitations of actual equipment, including
20 the relatively large size of the light source and the light
elements themselves, dictate that the relatively narrow
band of light provided by the described optical and
mechanical elements has a vertical dimension in the order
of $1/3$ to $1/2$ of the vertical dimension H of the liquid
25 crystal light valve active area. The vertical dimension of
the narrow light band is indicated by reference character
 h . The vertical height h of the horizontal light band 80,
may be decreased by employing a narrow horizontally
extending slit to limit the size of the light source.
30 However, such an arrangement would decrease efficiency of
use of the light source because of the lost light that is
blocked and prevented from passing through the slit.
Nevertheless, the narrower beam will provide even greater
contrast in the output illumination of the liquid crystal
35 light valve so that there may be a useful tradeoff
depending upon desired parameters and operation of the

1 system, wherein an increased contrast obtained by employing
a slit to further decrease reading light height is
preferred even at the cost of some additional loss of
efficiency. The actual effective height of the band 80 is
5 significantly decreased by the fact that light intensity
across the height of the band has a Gaussian distribution
that peaks at the band centerline.

It will be seen, as viewed in FIG. 2, that effectively
there is provided a train of end to end light bending
10 elements, circular in form in this embodiment, which are
moved so as to be successively interposed at varying angles
as each lens element moves between the light source and the
display to refract the beam and cause the horizontally
wide, vertically narrow beam to scan vertically between the
15 top and bottom of the liquid crystal area. The refracted
beam is shaped into a relatively narrow band or line of
light at the light valve by the described negative
cylindrical lens and the plano-convex lens which collimates
the divergent axis of the beam. Width of the reading light
20 scanning line is narrowest when all of the light rays of
the beam impinging on the scan wheel are collimated.

From the temporal variation of light intensity for any
fixed position, as shown in FIG. 6, it can be seen that
intensity of the average reflected light over one field
25 time is much less than intensity of the peak reflected
light. According to the present invention, the reading
light is compressed vertically, in the vertical scan
direction, as shown in FIG. 7, and tracks the peak of light
valve response as it moves vertically with the scan of the
writing light. This raises the average reflected light
30 over the field time of the input raster at any given point
nearly to the previous peak value. Although the reading
illumination moves in synchronism with the writing
illumination, it is actually preferably moved at a location
35 slightly behind the position of the writing light
illumination so as to track more closely the moving peak of

1 light valve response, rather than the moving peak of input
writing scan. As previously mentioned, the peak of light
valve output response, as shown in FIG. 6, is slightly
behind the writing input raster scan.

5 The "contrast" in the output of the liquid crystal
light valve (which is reduced by the temporal decay of
intensity) is the ratio of the intensity of light reflected
from an area of a liquid crystal illuminated by input light
compared to the intensity of light reflected from an area
10 of the liquid crystal that is "dark" or not illuminated by
input light.

When the liquid crystal light valve receives no input
light, there is still a small amount of light reflected at
the output side, that is, it still reflects somewhat in the
15 "dark" condition. The average output light divided by the
off state or "dark" state light determines the contrast
ratio of the projected image. Because the average output
light is raised by the synchronized scanning of reading
light described herein, but much of the off state or "dark"
20 state light is not affected (because the liquid crystal is
constantly in the orientation which gives minimum projected
light), the contrast ratio of the output illumination is
also increased by the techniques describes herein. As
previously noted, the distribution of reading light
25 intensity over the relatively narrow width of the reading
band 80 is of a Gaussian nature, so that the true peak
intensity of the narrowed band of reading light impinging
on the liquid crystal is of even smaller vertical extent.

Motor 54 is operated under control of a wheel rotation
30 control circuit 92 (FIG. 1), which receives synchronizing
signals from a cathode ray tube control circuit 94. The
latter provides horizontal and vertical scan control
signals on lines 96,98 to control the rectangular raster
scan of the cathode ray tube. The control circuit also
35 provides a vertical sync signal on a line 100, and a
multiplied sync signal, such as a signal having three

1 pulses for each vertical sync, on a line 102. Signals on
lines 100 and 102 are provided as reference signals to
wheel rotation control circuit 92, which receives speed
sensing signals from pickoffs 104, 106 on the output shaft
5 of motor 54. The pick offs provide a signal on a line 108
representing one pulse per rotation and a signal on a line
110 representing one pulse for each one of the three light
bending lens elements on the wheel.

Further details of wheel control circuit 92 are
10 illustrated in FIG. 8, which shows a first phase detector
114 having a reference input on line 116 from the vertical
sync pulse of the CRT control circuit on line 118 and a
variable input on line 120 from the pickoff 104 that
provides one pulse per wheel rotation. Initially a first
15 output on a line 122 of phase detector 114 is provided to
a first terminal 123 of a switch 124, having a second
terminal 126 connected via an adjustment potentiometer 128
to a fixed source of potential. Initially the switch is
connected to the fixed source of potential and provides an
20 output via a summing error filter and amplifier 130 through
a motor power amplifier 134 to the motor 54. Motor 54 may
be, for example, a brushless DC motor that drives the wheel
52 with a controlled speed that is to be synchronized with
the vertical field of the CRT.

25 Upon occurrence of a vertical sync pulse on line 118,
a pulse detector 136 operates switch 124 to move it to its
second position so that phase detector 114 now will send a
speed control signal via amplifier 130 to the motor that
locks the motor rotation speed to the vertical
30 synchronization of the writing input from the CRT. The
motor lock to the vertical sync rate and phase causes a
lock signal on a second output line 138 of phase detector
114, which operates a second switch 140 to connect the
output on a line 142 of a second phase detector 144 to the
35 input of summing error filter and amplifier 130. The
second phase detector 144 receives a reference input on

1 line 150 that is the three pulse per revolution signal on
line 102 of FIG. 1, derived from the cathode ray tube
control electronics, which may be merely a plurality of
pulses equally spaced between successive vertical sync
5 pulses to provide three pulses per revolution. A reference
input to the second phase detector 144 is provided on an
input line 152 from a group of pickoffs on the rotating
wheel arranged to provide one pulse at each intersection of
the three successive 120° light bending elements wheel.
10 Thus the dual phase detector arrangement ensures first that
the wheel speed be such as to cause each of the three light
bending lens elements of a train of elements on the wheel
to traverse the light beam path with the same speed as the
vertical scan of the writing input, and, second, that a
15 selected one of the respective lens elements moves in phase
with the vertical sync pulse.

Illustrated in FIG. 9 is an arrangement where light
bending elements comprise reflective rather than refractive
elements. The arrangement of FIG. 9 employs the same major
20 projection components as does the arrangement of FIG. 1,
including the liquid crystal light valve 10, CRT 12,
MacNeille prism 28, output projection lens 42, and xenon
arc lamp 16 with its cold mirrors 18 and 20. In this
arrangement also there is a wheel 52a corresponding to
25 wheel 52 of FIG. 1, driven by a motor 54a and having a
plurality of reflective lens elements 56a, 58a, 60a (FIGS.
10 and 11) corresponding to the similarly numbered
refractive elements of FIG. 1. In this system each bending
element is mounted on one side of the wheel and has a
30 continuously changing different reflective angle (as the
wheel rotates) analogous to the continuously changing
refractive angle elements of FIGS. 1 and 2. Consequently,
light from the arc lamp is reflected in a repetitive
vertical scanning pattern as the wheel 52a rotates. The
35 vertically scanning light is spread horizontally by the
negative cylindrical lens element 70a, and thence fed

1 through the plano-convex lens element 72a, just as
previously described in connection with FIG. 1. Electronic
control for the wheel with the three reflective elements is
the same for both the reflective and refractive
5 embodiments.

The light bending elements of the arrangements of
FIGS. 1 and 9 as described to this point may be free of any
color imparting characteristics so that the video
projection will be in black and white and shades of gray.
10 However, the elements are grouped in threes, with a total
number of elements on the wheel that is three or some
integral multiple of three, so that successively different
ones of the elements may be made of successively different
ones of the three primary red, green and blue colors. Such
15 a color system is employed where the cathode ray tube
provides a sequential color scan, scanning red, blue and
green fields in sequence, and employing 180 fields per
second. The red, green and blue fields can be
non-interlaced or interlaced with another set of red, green
20 and blue fields to provide a single frame. Where the
projector is to be a color projector, the refractive
bending elements 56, 58 and 60 are provided with suitable
color coatings on the flat face thereof, namely that face
which is against the wheel (the various elements are
25 fixedly mounted on the flat surface of the wheel). So,
too, the reflective elements may be suitably coated with
color selecting reflective coatings, so that the reading
light that is caused to illuminate the liquid crystal
active area changes in color from field to field in
30 sequence, with the three color sequence repeating for each
wheel rotation or several times per rotation.

It will be readily understood that, although a train
of three light bending elements, each extending for 120°
around the periphery of the wheel, has been illustrated, if
35 a color arrangement is desired, the number of bending
elements may be any integral multiple of three, with the

1 length of each element being proportionately less so that
a train of six, nine or twelve or more elements are
positioned end to end, forming a continuous circular train
of bending elements that are successively interposed
5 between the light source and the liquid crystal as the
wheel rotates. In such a situation, where more than three
light bending elements are employed on a single wheel, the
speed of the wheel is proportionately decreased so that the
traverse of each individual element, or more specifically
10 the traverse of the reading beam deflection caused by each
specific individual element, is synchronized with a full
vertical scan of the input writing raster. Thus, although
rotational speed of the wheel is not a limiting factor, the
rotational speed is decreased as the number of groups of
15 three different color elements of the train increases.

CLAIMSWhat is Claimed is:

- 1 1. In a liquid crystal light valve wherein a liquid
crystal is optically addressed by an input write beam that
scans the area of said liquid crystal in a writing scan,
and wherein high intensity reading light illuminates the
5 active area of said liquid crystal to be reflected for
display, an improved method for illuminating said liquid
crystal active area comprising:
 projecting a high intensity reading light to
illuminate part of the active area of said liquid crystal,
10 and
 scanning said illuminated area over said liquid
crystal in synchronism with said writing scan.
- 1 2. The method of Claim 1 wherein said input write
beam scans in a line by line writing scan, and wherein said
step of scanning said illuminated area comprises scanning
a band of reading light in synchronism with said writing
5 scan.
- 1 3. The method of Claim 1 wherein said steps of
projecting and scanning comprise providing a high intensity
light source, projecting reading light from said source to
said liquid crystal, providing a train of quasi cylindrical
5 light bending elements, and moving said lens elements in
sequence between said light source and said liquid crystal.
- 1 4. The method of Claim 3 wherein said step of
providing a train of lens elements comprises providing
elongated refractive lens elements having varying
refractive angles along their length.

1 5. The method of Claim 3 wherein said step of
providing lens elements comprises providing elongated
reflective lens elements having varying reflective angles
along their length.

1 6. The method of Claim 3 including the step of
synchronizing the moving of said lens elements with said
writing scan.

1 7. The method of Claim 1 wherein said step of
projecting comprises shaping the projected reading light to
a narrow elongated area at said liquid crystal active area.

1 8. The method of Claim 3 wherein said step of
providing lens elements comprises mounting a plurality of
circularly curved quasi cylindrical lens elements on a
wheel and wherein said step of moving said lens elements in
5 sequence comprises rotating said wheel.

1 9. The method of Claim 1 wherein said steps of
projecting and scanning comprise shaping said reading light
to a narrow band and repetitively bending said shaped
reading light to cause it to scan said liquid crystal
5 active area in synchronism with said writing scan.

1 10. The method of Claim 9 wherein said bending
comprises repetitively refracting said reading light.

1 11. The method of Claim 9 wherein said bending
comprises repetitively reflecting said reading light.

1 12. The method of Claim 3 wherein said step of
providing a train of light bending elements comprises
providing a train of light bending elements of sequentially
different colors.

1 13. In a liquid crystal light valve having an input
face that is scanned with a scan of input illumination and
having an output face with an active area for receiving
reading illumination, a method for illuminating said output
5 face comprising:

 projecting at said output face a reading light
beam having a cross section defining a reading area that is
smaller than the area of said output face, and

 moving said area of reading light over said
10 output face in synchronism with said scan of input
illumination.

1 14. The method of Claim 13 wherein said step of
projecting comprises providing a circular array of
individual beam bending elements, projecting a beam of
reading light to a portion of one of said elements, and
5 rotating said array relative to said beam to cause said
beam to traverse said elements in synchronism with said
raster scan of input illumination.

1 15. The method of Claim 13 wherein said input face is
scanned with a line of input illumination that moves over
said input face, and wherein said step of projecting
comprises shaping said beam of reading light into a narrow
5 band.

1 16. The method of Claim 14 wherein said input face is
scanned with a line of input illumination that moves over
said input face, and including the step of shaping said
projected beam of reading light into a band after it is
5 bent by said beam bending elements.

1 17. The method of Claim 16 wherein said array is
rotated to synchronize motion of each of said bending
elements, individually, with said raster scan of input
illumination.

1 18. A liquid crystal light valve projector
comprising:

an input face and an output face having an active
area,

5 means for scanning said input face with a raster
scan of input illumination, and

means for illuminating said output face active
area comprising:

10 means for projecting at said output face a
projection area of reading light that is smaller
at said output face than the active area of said
output face, and

15 means included in said means for projecting
for moving said projection area of reading light
over said output face active area in synchronism
with said scan of input illumination.

1 19. The projector of Claim 18 wherein said means for
moving said projection area of reading light scan comprises
a wheel, means for rotating the wheel in synchronism with
said scan of input illumination, and a plurality of light
5 bending elements on said wheel and positioned to bend said
reading light to different parts of said liquid crystal
active area as the wheel rotates.

1 20. The liquid crystal projector of Claim 19 wherein
said light bending elements comprise a train of light
refractive elements positioned in end to end relation on
said wheel.

1 21. The projector of Claim 20 wherein said light
bending elements comprise a train of light reflective
elements positioned in end to end relation on said wheel.

1 22. The projector of Claim 20 wherein said scan of
input illumination includes a plurality of successive
fields, wherein said bending elements of said plurality of
bending elements are formed in at least one group of three,
5 and wherein each of said bending elements of said one group
has a different color, whereby the reading light impinging
upon said liquid crystal active area is a different color
for each field of each group of three successive fields.

1 23. The projector of Claim 20 wherein said means for
scanning said input face with a scan includes an input
raster scan control having a vertical sync signal, and
wherein said means for moving said projection area of
5 reading light comprises means for rotating said wheel at a
speed synchronized from said vertical synch signal.

1 24. A liquid crystal light valve projector
comprising:

 a liquid crystal light valve having an input face
and having an output face with an active area,

5 means for optically addressing the liquid crystal
light valve by an input light beam that scans said input
face in a writing scan, and

 high intensity reading light means for
illuminating said output face to provide a reflected image
10 for display, said high intensity reading light means
comprising:

 high intensity light source means for
generating a high intensity projection beam,

 means for shaping said projection beam into
15 a reading beam having a reading area smaller than
said active area of said output face, and

 means for causing said reading area to scan
said active area in synchronism with said writing
scan.

1 25. The projector of Claim 24 wherein said means for
shaping comprises means for shaping said projection beam
into a narrow band of reading light.

1 26. The projector of Claim 24 wherein said means for
shaping comprises a negative cylindrical lens.

1 27. The projector of Claim 24 wherein said means for
shaping comprises a negative cylindrical lens and a
planoconvex lens.

1 28. The projector of Claim 25 wherein said means for
optically addressing includes means for causing said input
light beam to scan said input face in a line by line
writing scan, and wherein said means for causing said
5 reading area to scan comprises scanning said narrow band of
reading light in synchronism with said line by line writing
scan.

1 29. The projector of Claim 24 wherein said means for
causing said reading area to scan said active area
comprises a wheel, a plurality of narrow elongated light
bending elements on an outer circumferential portion of
5 said wheel and positioned in end to end relation along said
circumferential portion, said circumferential portion and
said bending elements being interposed between said liquid
crystal active area and said light source means, and means
responsive to said means for optically addressing for
10 rotating said wheel in synchronism with said writing scan.

AMENDED CLAIMS

[received by the International Bureau on 20 September 1994 (20.09.94);
original claim 3 cancelled; new claims 30-33 added;
remaining claims amended (6 pages)]

1. In a liquid crystal light valve wherein a liquid crystal is optically addressed by an input write beam that scans the area of said liquid crystal in a writing scan, and wherein high intensity reading light illuminates the active area of said liquid crystal to be reflected for display, an improved method for illuminating said liquid crystal active area comprising:

projecting a high intensity reading light to illuminate part of the active area of said liquid crystal;

scanning said illuminated area over said liquid crystal in synchronism with said writing scan; and

wherein said steps of projecting and scanning comprise providing a high intensity light source, projecting reading light from said source to said liquid crystal, providing a train of quasi cylindrical light bending elements, and moving said light bending elements in sequence between said light source and said liquid crystal.

2. The method of Claim 1 wherein said input write beam scans in a line by line writing scan, and wherein said step of scanning said illuminated area comprises scanning a band of reading light in synchronism with said writing scan.

4. The method of Claim 1 wherein said step of providing a train of light bending elements comprises providing elongated refractive lens elements having varying refractive angles along their length.

5. The method of Claim 1 wherein said step of providing light bending elements comprises providing elongated reflective lens elements having varying reflective angles along their length.

6. The method of Claim 1 including the step of synchronizing the moving of said light bending elements with said writing scan.

7. The method of Claim 1 wherein said step of projecting comprises shaping the projected reading light to a narrow elongated area at said liquid crystal active area.

8. The method of Claim 1 wherein said step of providing light bending elements comprises mounting a plurality of circularly curved quasi cylindrical lens elements on a wheel and wherein said step of moving said lens elements in sequence comprises rotating said wheel.

9. The method of Claim 1 wherein said steps of projecting and scanning comprise shaping said reading light to a narrow band and repetitively bending said shaped reading light to cause it to scan said liquid crystal active area in synchronism with said writing scan.

10. The method of Claim 9 wherein said bending comprises repetitively refracting said reading light.

11. The method of Claim 9 wherein said bending comprises repetitively reflecting said reading light.

12. The method of Claim 1 wherein said step of providing a train of light bending elements comprises providing a train of light bending elements of sequentially different colors.

13. In a liquid crystal light valve having an input face that is scanned with a scan of input illumination and having an output face with an active area for receiving reading illumination, a method for illuminating said output face comprising:

- projecting at said output face a reading light beam having a cross section
- 5 defining a reading area that is smaller than the area of said output face;
- moving said area of reading light over said output face in synchronism with said scan of input illumination; and

AMENDED SHEET (ARTICLE 19)

wherein said steps of projecting and scanning comprise providing a high intensity light source, projecting reading light from said source to said liquid crystal, providing
10 a train of quasi cylindrical light bending elements, and moving said light bending elements in sequence between said light source and said liquid crystal.

14. The method of Claim 13 wherein said step of projecting comprises providing a circular array of individual beam bending elements, projecting a beam of reading light to a portion of one of said elements, and rotating said array relative to said beam to cause said beam to traverse said elements in synchronism with said raster
5 scan of input illumination.

15. The method of Claim 13 wherein said input face is scanned with a line of input illumination that moves over said input face, and wherein said step of projecting comprises shaping said beam of reading light into a narrow band.

16. The method of Claim 14 wherein said input face is scanned with a line of input illumination that moves over said input face, and including the step of shaping said projected beam of reading light into a band after it is bent by said beam bending elements.

17. The method of Claim 16 wherein said array is rotated to synchronize motion of each of said bending elements, individually, with said raster scan of input illumination.

18. A liquid crystal light valve projector comprising:
an input face and an output face having an active area,
means for scanning said input face with a raster scan of input illumination, and
means for illuminating said output face active area comprising:
5 means for projecting at said output face a projection area of reading light that is smaller at said output face than the active areas of said output face;

AMENDED SHEET (ARTICLE 19)

means included in said means for projecting for moving said projection area of reading light over said output face active area in synchronism with said scan of input illumination; and

- 10 wherein said steps of projecting and scanning comprise providing a high intensity light source, projecting reading light from said source to said liquid crystal, providing a train of quasi cylindrical light bending elements, and moving said light bending elements in sequence between said light source and said liquid crystal.

19. The projector of Claim 18 wherein said means for moving said projection area of reading light scan comprises a wheel, means for rotating the wheel in synchronism with said scan of input illumination, and a plurality of light bending elements on said wheel and positioned to bend said reading light to different parts of
5 said liquid crystal active area as the wheel rotates.

20. The liquid crystal projector of Claim 19 wherein said light bending elements comprise a train of light refractive elements positioned in end to end relation on said wheel.

21. The projector of Claim 19 wherein said light bending elements comprise a train of light reflective elements positioned in end to end relation on said wheel.

22. The projector of Claim 20 wherein said scan of input illumination includes a plurality of successive fields, wherein said bending elements of said plurality of bending elements are formed in at least one group of three, and wherein each of said bending elements of said one group has a different color, whereby the reading light
5 impinging upon said liquid crystal active area is a different color for each field of each group of three successive fields.

23. The projector of Claim 20 wherein said means for scanning said input face with a scan includes an input raster scan control having a vertical sync signal, and wherein said means for moving said projection area of reading light comprises means for rotating said wheel at a speed synchronized from said vertical sync signal.

AMENDED SHEET (ARTICLE 19)

24. A liquid crystal light valve projector comprising:
a liquid crystal light valve having an input face and having an output face
with an active area;
means for optically addressing the liquid crystal light valve by an input
5 light beam that scans said input face in a writing scan; and
high intensity reading light projecting means for illuminating said output face to
provide a reflected image for display, said high intensity reading light means
comprising:
high intensity light source means for generating a high intensity
10 projection beam;
means for shaping said projection beam into a reading beam having
a reading area smaller than said active area of said output face, and
means for causing said reading area to scan said active area in
synchronism with said writing scan; and
15 said means for projecting including high intensity light source for
projecting reading light from said source to said liquid crystal light
bending elements and means for moving said light bending elements in
sequence into position between said light source and said liquid crystal.
25. The projector of Claim 24 wherein said means for shaping comprises
means for shaping said projection beam into a narrow band of reading light.
26. The projector of Claim 24 wherein said means for shaping comprises a
negative cylindrical lens.
27. The projector of Claim 24 wherein said means for shaping comprise a
negative cylindrical lens and a planoconvex lens.
28. The projector of Claim 25 wherein said means for optically addressing
includes means for causing said input light beam to scan said input face in a line
writing scan, and wherein said means for causing said reading area to scan comprises

scanning said narrow band of reading light in synchronism with said line by line writing
5 scan.

29. The projector of claim 24 wherein said means for causing said reading area to scan said active area comprises a wheel, a plurality of narrow elongated light bending elements on an outer circumferential portion of said wheel and positioned in end to end relation along said wheel and positioned in end to end relation along said
5 circumferential portion, said circumferential portion and said bending elements being interposed between said liquid crystal active area and said light source means, and means responsive to said means for optically addressing for rotating said wheel in synchronism with said writing scan.

30. In a liquid crystal light valve wherein a liquid crystal is optically addressed by an input write beam that scans the ares of said liquid crystal in a writing scan, and wherein high intensity reading light illuminates the active area of said liquid crystal to be reflected for display, an improved method for illuminating said liquid crystal active
5 area comprising:

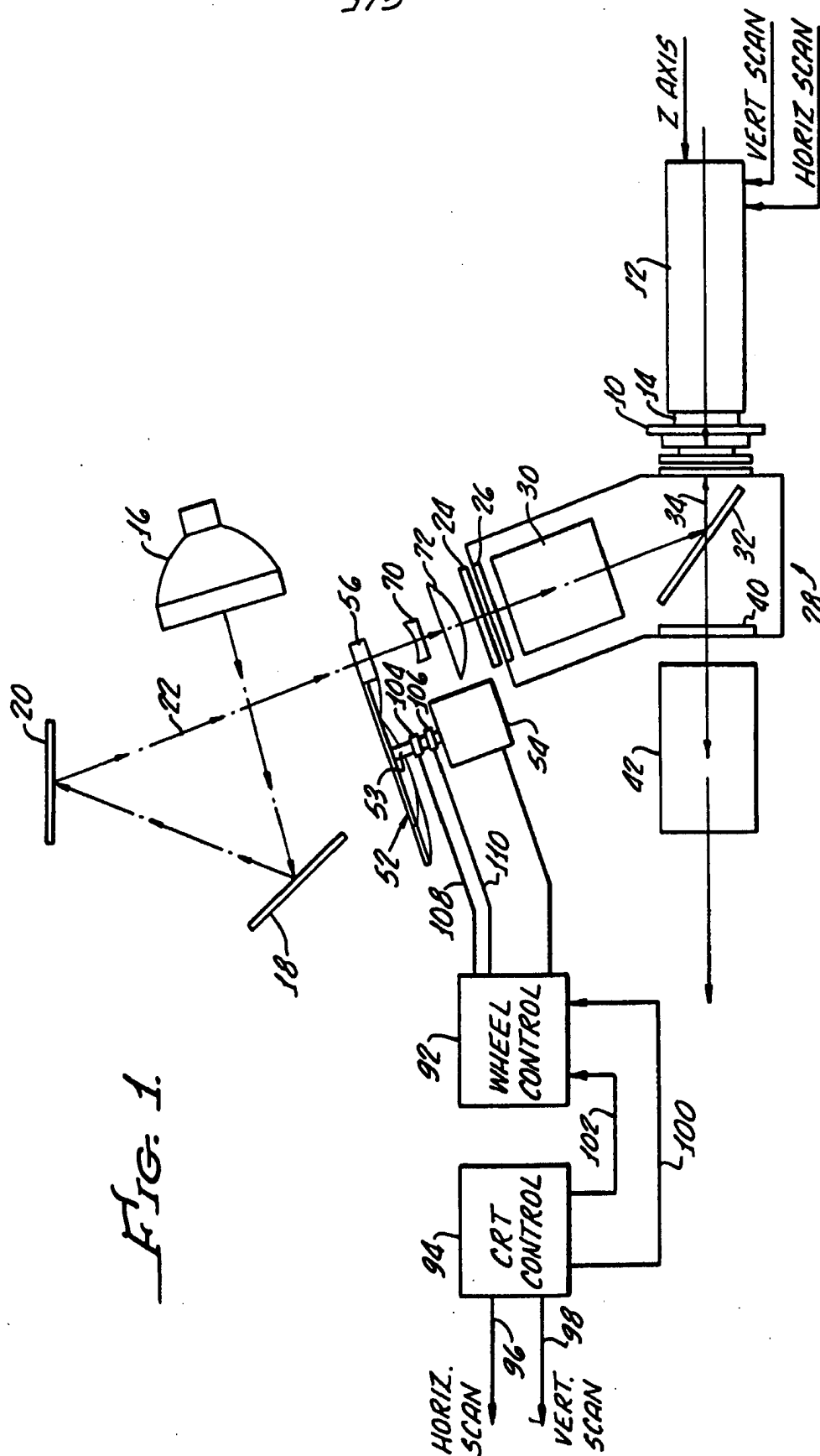
projecting a band of reading light to illuminate less than the entire active area of said liquid crystal, and

moving said band of reading light over said liquid crystal in synchronism with said writing scan such that the band of reading light illuminates the scanned area of said
10 liquid crystal as it is being optically addressed by said input write beam, wherein said steps of projecting and scanning comprise shaping said reading light to a narrow band and repetitively bending said shaped reading light to cause it to scan said liquid crystal active ares in synchronism with said writing scan.

32. The method of Claim 30 wherein said bending comprises repetitively refracting said reading light.

33. The method of claim 30 wherein said bending comprises repetitively reflecting said reading light.

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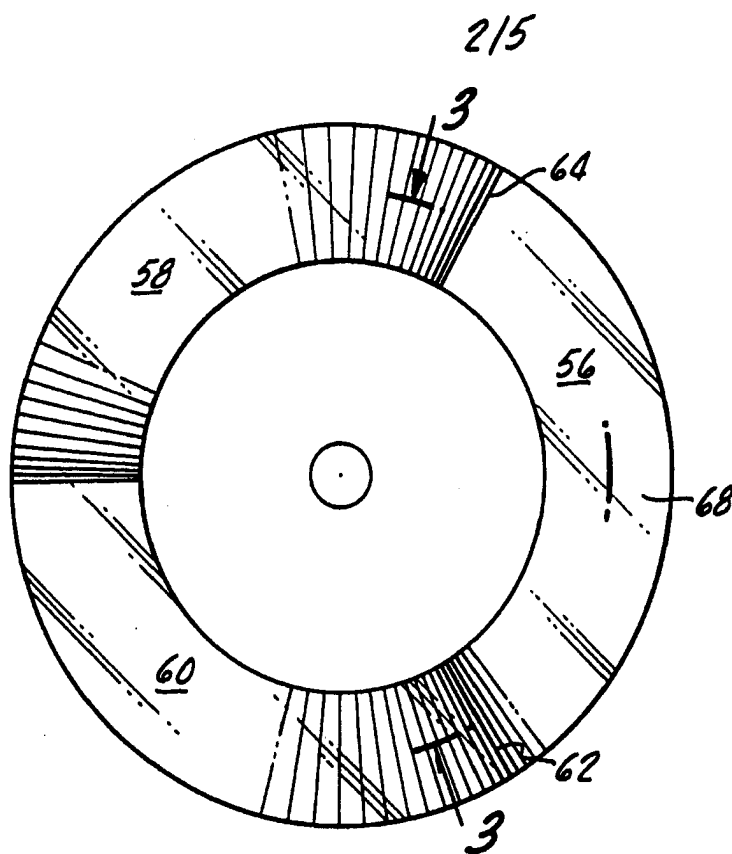


FIG. 2.

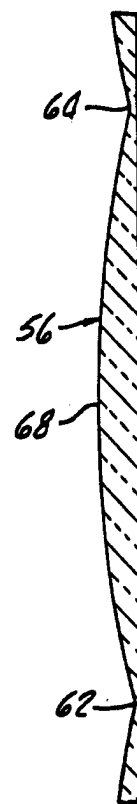


FIG. 3.

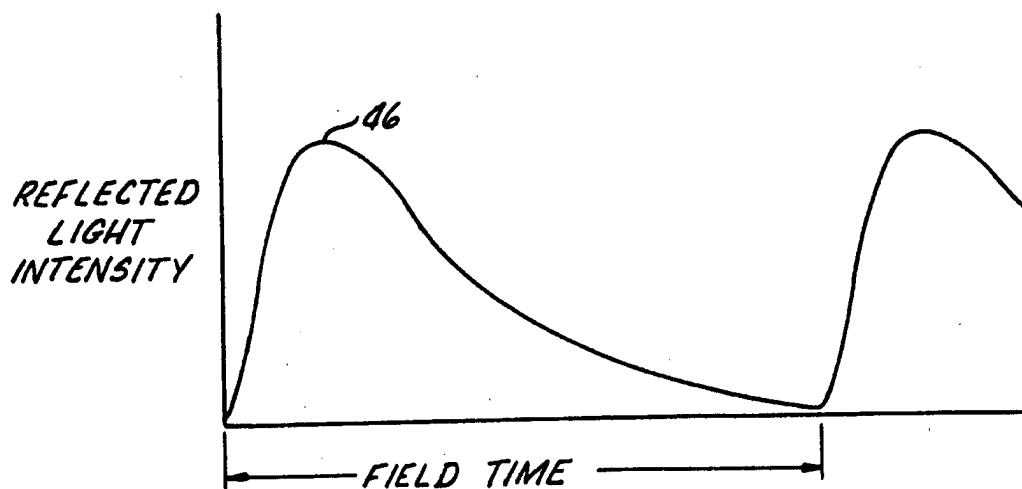


FIG. 6.

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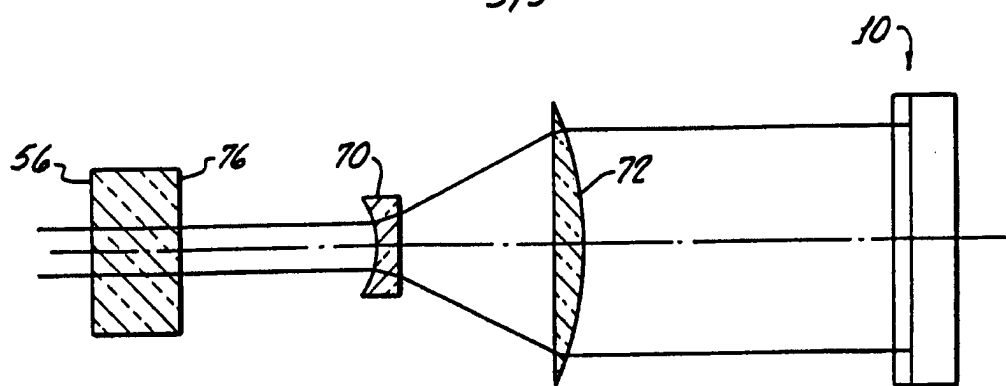


FIG. 4.

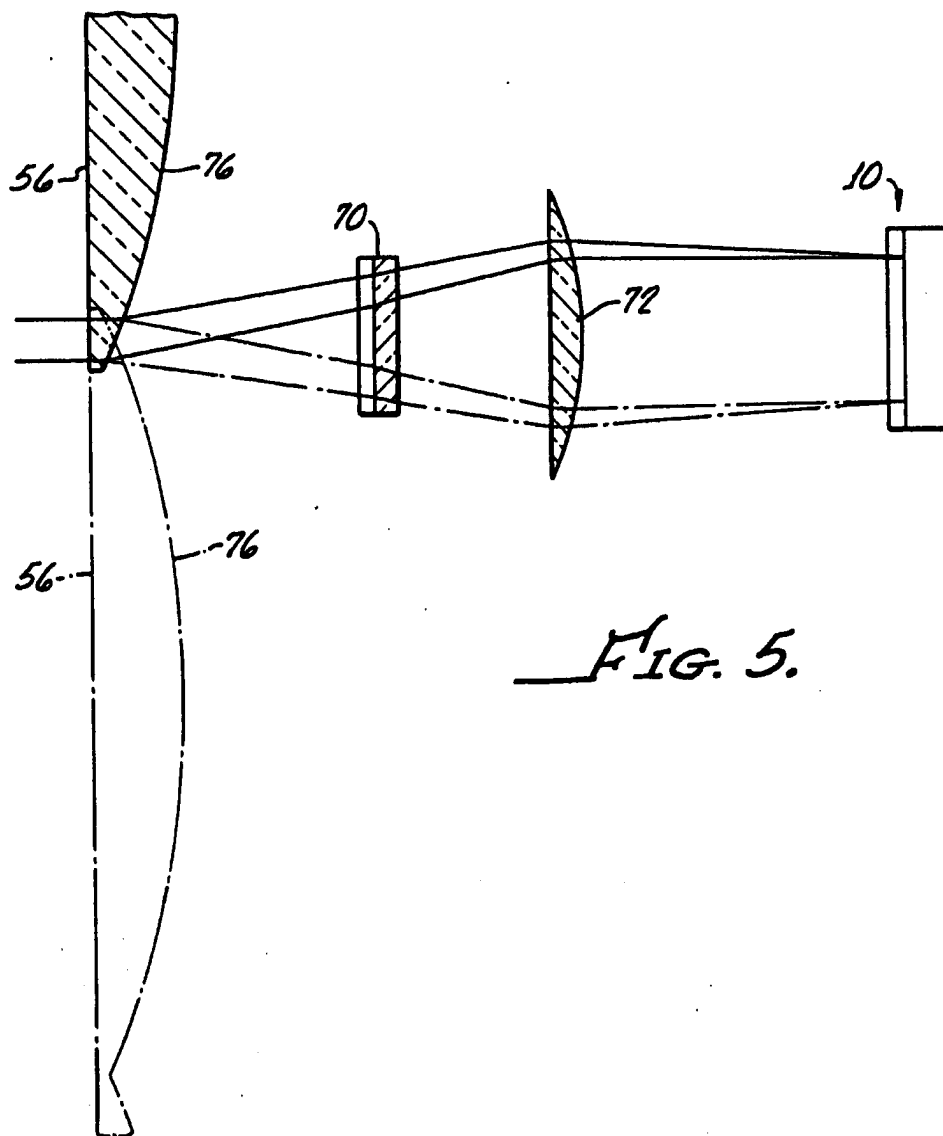
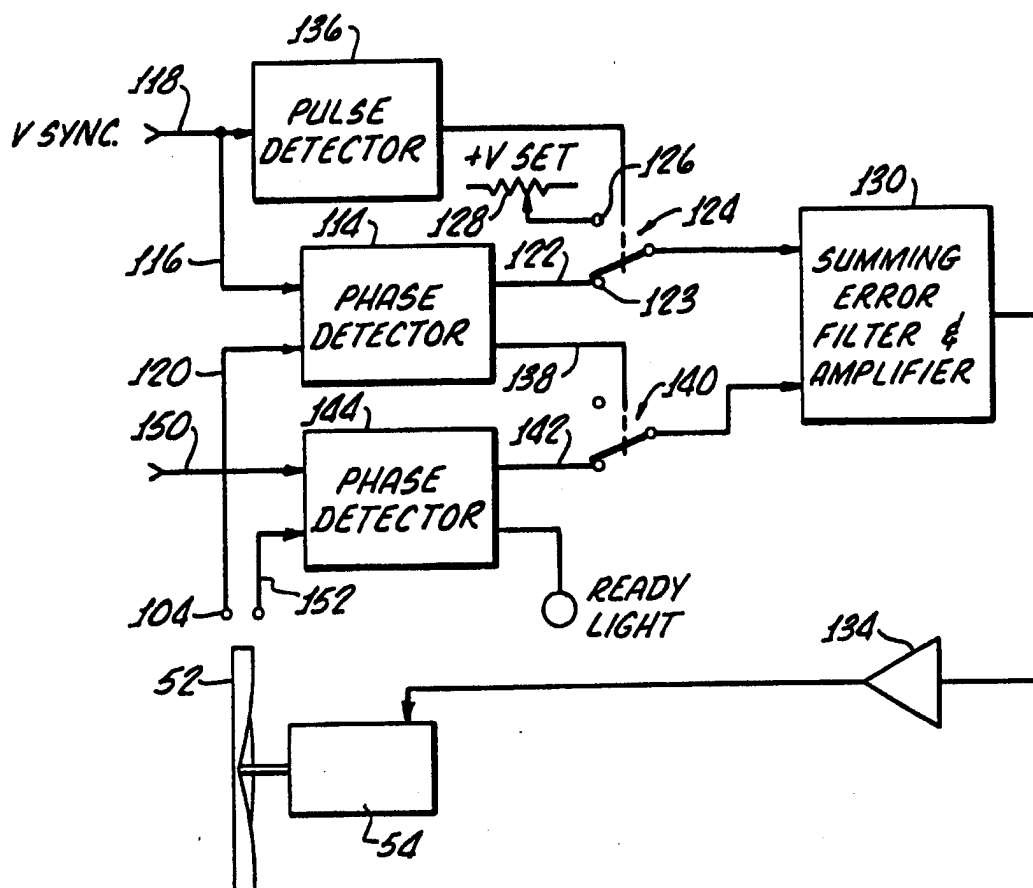
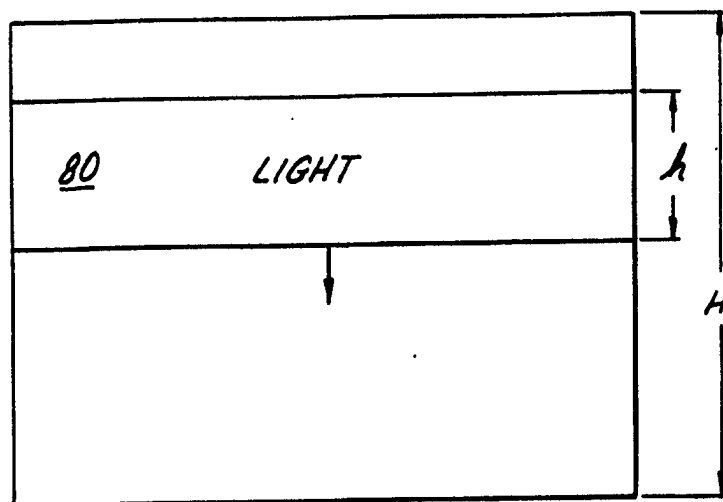


FIG. 5.

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FIG. 9.

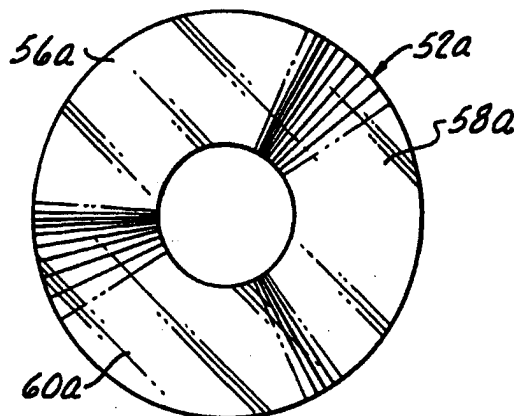
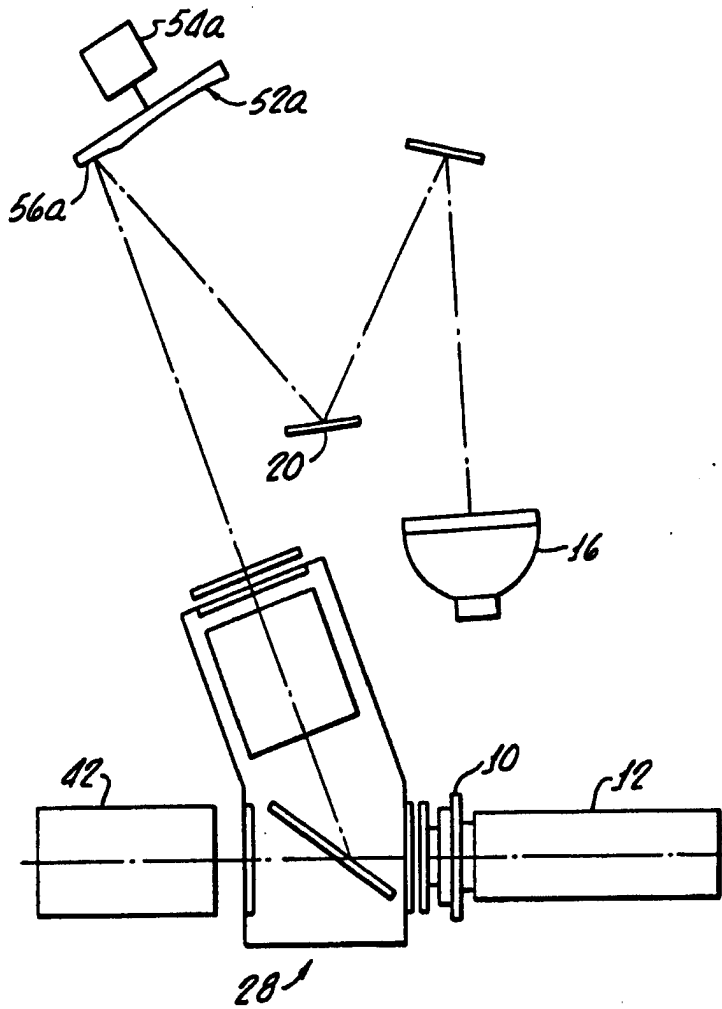


FIG. 10.

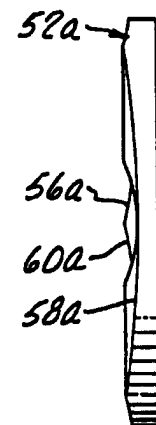


FIG. 11.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03465**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) :H04N 3/06, 3/08, 3/00

US CL :348/764, 760, 781; 359/45, 210; 353/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,192,946 (THOMPSON et al.) 09 March 1993, column 6, line 21 to column 7, line 48 and Fig. 1a.	1,2,7,9-29
Y	US, A, 4,641,192 (DIEPEVEEN et al.) 03 February 1987, Fig 2.	1, 2, 7, 9, 11-19,24,25-29
Y	US, A, 1,544,156 (JENKINS) 30 June 1925, Fig.3	1,2,7,9,10, 13-29
Y	US, A, 2,588,740 (MALM) 11 March 1952, Fig. 11,2,7,9,10, 13-2	1,2,7,9,10, 13-29
Y	US, A, 4,641,038 (BAKER) 03 February 1987, Fig. 2	1,2,7,9,10, 13-29

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

26 JUNE 1994

Date of mailing of the international search report

SEP 08 1994

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Telephone No. (703) 305-4741

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03465

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,107,070 (WILLIS et al.) 15 October 1963, Fig. 1.	26,27
A	US, A, 2,064,475 (IVES) 15 December 1936, Fig. 1	1-3,8-10,12-14,17-20
A	US, A, 4,127,322 (JACOBSON et al.) 28 November 1978, Figs. 1, 2.	1
A	US, A, 2,976,362 (STAMPS) 21 March 1961, Figs. 1-12	1-3,8-10,12-14,17-20
A	US, A, 2,958,783 (TAYLOR) 01 November 1960, Fig. 1.	1,9-11,18,19,21
A	US, A, 4,268,110 (FORD) 19 May 1981, Figs. 1,2.	1,9-11,18,19,21

Form PCT/ISA/210 (continuation of second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US94/03465

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

US CL: 348/195-197, 199, 201-205, 759-764, 766-768, 781, 782, 742-744, 786, 790-792, 832, 835, 751-753, 755, 756, 763, 764, 770, 771, 776, 779; 359/40, 45, 209-211, 216; 353/31, 38, 100-102; 358/60-64, 58, 55, 231-234, 236, 237, 199, 200, 202, 205-208; HO4N 3/06, 3/08, 3/00, 5/74, 9/14, 9/31